

would save \$2.2 billion, and even the modest cuts under Case 3 would save \$1.0 billion. Table 8 shows the 1992 savings in more detail. 4/

Personnel costs will rise in real terms between 1987 and 1992 under even the most severe alternative for strength cuts (Case 1). The Case 1 cuts would limit the cost increase to \$1.5 billion, however--a little more than half the increase that would occur if the services' strength plans were carried out. Costs rise even when strength levels are cut because real pay levels must grow if private-sector pay increases are to be matched and, to a lesser extent, because of seniority growth. As shown in Chapter II, seniority growth will add at least \$420 million, and possibly as much as \$720 million, to 1992 costs.

The savings are evident when the costs of the three alternatives are compared with the costs under the services' strength plans (bottom panel, Table 8). 5/ Under Case 1, 1992 savings would range from 1.2 percent for the Army to 4.1 percent for the Marine Corps, with a 2.2 percent saving overall. That 2.2 percent amounts to \$1.2 billion, with the Navy alone accounting for almost \$500 million. The Case 2 savings--1.5 percent overall--would be nearly \$800 million. To put these savings in perspective, the Case 1 strength cuts would reduce 1992 defense costs by nearly as much as cutting two percentage points off the 1988 military pay raise, a cut that would reduce the pay of officers as well as enlistees. 6/

Accession Requirements

A side benefit of strength reductions would be an easing of recruiting pressures, which some have seen as a serious concern in the 1990s. Although accession requirements would fall only slightly in the long run, large reductions would occur in the years in which the strength cuts were made and again when the smaller entry cohorts reached reenlistment points. Thus, strength cuts could be timed to ease recruiting difficulties, should they arise.

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4. The cost savings were projected under the assumption that richer grade mixes would be permitted (see Chapter II). Savings are virtually identical, however, under the alternative assumption of no changes in aggregate grade mixes.
 5. Measured relative to the CBO baseline projections of the federal budget, savings would fall between those measured relative to 1987 and those measured relative to the service plans.
 6. Congressional Budget Office, *Reducing the Deficit: Spending and Revenue Options* (January 1987), pp. 59-60.

To give a specific example, the cuts under Case 2 would reduce the total requirement for nonprior-service (NPS) accessions by 4.7 percent in 1988 and by 6.5 percent in 1991, relative to requirements under the services' strength plans. By service, reductions in 1988 would range from zero percent for the Navy (16.5 percent in 1991) to 8.8 percent for the Marine Corps. Total NPS requirements over the five years 1988 through 1992 would fall by 3.6 percent. Reductions of this magnitude would not completely offset the effects of smaller enlistment-age cohorts in the 1990s, but could be of significant help if problems arose with the quality of recruits.

CONCLUSIONS

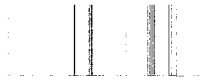
The alternatives presented in the previous section should not be construed as recommendations for strength reductions, either from current levels or from levels planned for the future. Rather, they should be taken as indications of the magnitudes of reductions that might be justified following a more complete examination of experience/productivity trade-offs in the military. The data underlying this study are too limited to provide a firm basis for decisions on enlisted strength levels. Nonetheless, the main strength-level alternatives--Case 1 and Case 2--are based on the best information currently available, and so should not be completely discounted. Particularly noteworthy are the possible cost savings if aggregate productivity levels were used to set enlisted strength levels, rather than the reverse as is now implicitly done.

The results of this study should present a challenge to those who would permit or encourage the experience trends in the enlisted forces without any formal justification of the need for more seniority. Either they must accept that experience does enhance productivity, in which case strength cuts should be possible, perhaps along the lines of the Case 2 alternative above; or they can reject this implication and, by extension, reject the need for greater seniority. Tightened reenlistment standards, possibly accompanied by severance payments to the more senior personnel forced out, could limit the coming shifts. Cost savings on the order of \$500 million in 1992 should be possible if seniority growth were halted.

Acceptance of this study's productivity results need not necessarily mean acquiescence to personnel strength reductions. It could be argued that, however real the productivity gains accruing from more experienced personnel, those gains cannot be translated into improvements in aggregate capability that could be traded off against numbers. Some support for this view appears in the limitations identified at the end of Chapter III. Even if the

possibility of trading experience for numbers is granted, seniority growth appears to provide significant improvement in defense capability at fairly modest cost. If this study's results are used to justify the projected seniority growth, however, the costs and benefits must be compared with those of alternative means for improving capabilities, and of programs that might be sacrificed to pay for greater experience in the enlisted force.

The coming seniority growth, like that of the last decade, is a natural consequence of the switch to a wholly volunteer military. It can be exploited to improve defense capability or to ease the effects of defense budget cuts or slower growth; or its effects on productivity and costs can be ignored, as has largely been the case in the past. This study should serve to bring these alternatives under closer scrutiny.



APPENDIXES



APPENDIX A

PAY AND UNEMPLOYMENT ELASTICITIES

TABLE A-1. ASSUMPTIONS FOR PAY AND UNEMPLOYMENT ELASTICITIES, BY SERVICE AND YEAR OF SERVICE

Year of Service	Pay Elasticity				Unemployment Elasticity			
	Army	Navy	Marine Corps	Air Force	Army	Navy	Marine Corps	Air Force
1	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00
2	2.8	0.0	0.0	0.0	0.61	0.00	0.00	0.00
3	2.4	2.5	2.8	0.0	0.50	0.51	0.54	0.00
4	2.2	2.5	2.8	2.1	0.45	0.50	0.51	0.44
5	1.8	2.4	2.6	1.9	0.36	0.46	0.46	0.37
6	1.7	2.8	1.7	1.8	0.32	0.42	0.28	0.35
7	1.6	1.7	1.5	1.6	0.30	0.31	0.26	0.29
8	1.3	1.4	1.5	1.4	0.22	0.25	0.23	0.26
9	1.1	1.2	1.5	1.3	0.19	0.20	0.22	0.22
10	1.0	1.1	1.4	1.2	0.16	0.18	0.20	0.20
11	0.9	1.0	1.2	0.8	0.14	0.15	0.16	0.12
12	0.8	0.8	0.8	0.5	0.12	0.12	0.10	0.07
13	0.7	0.5	0.8	0.5	0.10	0.07	0.10	0.06
14	0.5	0.4	0.5	0.4	0.07	0.05	0.06	0.05
15	0.5	0.3	0.5	0.2	0.06	0.03	0.05	0.03
16	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00
17	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00
18	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00
19	0.0	0.5	0.0	0.0	0.00	0.10	0.00	0.00
20	2.5	2.8	2.6	2.2	0.33	0.34	0.30	0.27
21	2.4	1.9	2.1	2.1	0.29	0.26	0.26	0.27
22+	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00

SOURCE: Congressional Budget Office.

NOTE: These elasticities indicate the percentage change in the reenlistment rate at the given year of service resulting from a 1 percent change in the variable.

APPENDIX B

DEVELOPMENT OF PRODUCTIVITY INDEXES

FROM THE RAND AIR FORCE STUDY

The Air Force study did not produce a final report; the only published information on its findings appears in the text of a briefing. 1/ At CBO's request, the Air Force provided the data developed in the study, as well as a complete description of the study's methodology. The description, prepared by the study's principal investigator, included a number of cautions, to which the Air Force added several others; the cautions are detailed at the end of this appendix.

Data

The study divided the manpower in Aerospace Ground Equipment (AGE) maintenance into six labor types based on pay grade and skill level (an Air Force measure of proficiency). Labor-type 1, for example, consisted of all personnel in pay grades E-1 through E-3, and labor-type 4 of those in grade E-5 and with skill level 5 (the middle of three skill levels). On average, AGE personnel in labor-type 3 had completed four years of service, making this a useful reference group for computing relative productivities.

The data provided to CBO were of four general types:

- o Estimates of productivities by labor type, relative to the productivity for labor-type 3, for each of 13 AGE maintenance tasks. 2/
- o Estimates of "check time" by labor type and task; check time is the amount of time required for instruction/supervision/checking of one hour's work.

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1. S. Craig Moore, *Demand and Supply Integration for Air Force Enlisted Work Force Planning: A Briefing* (Santa Monica, Calif.: The RAND Corporation, N-1724-AF, August 1981).
 2. For brevity, this discussion refers to "tasks." In fact, each "task" comprised a group of tasks that were selected to be fairly homogeneous with respect to the types of workers who do them, the degree to which their performance improves with experience, and their changes in workloads over time. The groups generally contain about 8 to 25 tasks.

- o Information on monthly workloads by task.
- o Information on the constraints in the task-assignment problem that were developed in the study.

Relative Productivities by Task and Labor Type. Productivity estimates were provided by 24 AGE maintenance supervisors who evaluated 90 individual technicians working at two Air Force bases. Together, the 13 tasks for which the data were sufficient, two of them supervisory, accounted for about 75 percent of the work time of the AGE technicians; for the remaining 13 tasks performed in AGE maintenance, the data were too few for reliable estimates. Relative productivities differed greatly across the tasks. At one extreme, type-6 labor was 90 percent more productive than type-3 on one task, whereas on another task the two labor types were equally productive.

Check Time. Except in the simplest task, work by any labor type except type 6 generated a check-time requirement. For type 1, the check times averaged about 0.13 hours per hour worked across the 11 nonsupervisory tasks; for type 3, the average was about 0.06 hours. Even type-6 labor generated check-time requirements in four of the tasks, including both of the supervisory tasks.

Workloads. Separate monthly workloads, in hours, were provided for the nonsupervisory tasks at each of the two bases. These workloads differed substantially between the two bases, both in their totals and in their distributions across tasks. Workloads for the two supervisory tasks were generated by the check-time requirements for the other 11 tasks.

A specific example of the data appears below, showing the productivity, check-time, and workload data for one of the tasks. The top line shows the relative productivities; the entry for labor type 3 is 1.0 because that is the reference group. On this task, type-1 personnel are roughly 28 percent less productive, and type-6 personnel 41 percent more productive, than personnel of type 3. The last two columns give the monthly workloads at the two bases examined: 179 hours of type-3 labor or its equivalent at Norton AFB and 117 hours at March AFB. Finally, the bottom line shows the check times. For every hour that a type-3 person works on this task, for example, someone of a higher labor type must spend 0.098 hours (about six minutes) supervising, instructing, and checking the work.

	Labor Type						Requirements at AFBs	
	1	2	3	4	5	6	Norton	March
Relative Productivity	0.719	0.836	1.000	1.108	1.242	1.413	178.7	116.7
Check Time	0.155	0.131	0.098	0.068	0.031			

Constraints. The materials provided identified four sets of constraints that affect the allocation of labor types across tasks: workload constraints, forcing the workload requirements to be met; work-mix constraints, to ensure an appropriate mix of tasks for the personnel of each labor type; available time constraints, which specify the monthly hours per worker; and manning mix constraints, giving an upper and lower bound for the percentage of the work force in each labor type. ^{3/} Also provided were the actual percentages of AGE maintenance personnel in each labor type throughout the Air Force at the time of the study. As discussed below, this study used the latter figures, rather than the bounds identified in the manning mix constraints, to fix the distribution of labor types.

Methodology

The goal of this analysis is to determine relative productivities by labor type for the entire AGE maintenance work force. As noted in Chapter III, simply averaging across the 13 tasks would not be appropriate; no rational manager facing limited resources would assign the same mix of tasks to every person, as averaging implies. Instead, this study derived aggregate relative productivities after first determining the optimal assignments of personnel to tasks.

Optimality. Relative productivities are dependent on the labor-type mix of the available personnel (see below). Fixing the mix at the percentages

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3. The present study did not apply the available-time constraints because they merely represented the conversion from numbers of hours to numbers of people.

among all AGE maintenance personnel created a plausible measure of optimality: the fewer personnel required, the better the task assignments. With the mix across labor types fixed (for example, two type-1s for every type-3), minimizing the number of type-3s yields the same result as minimizing the total. Choosing to minimize type-3 labor means that all the productivities will be measured relative to this group, which with an average of four years of service is the same reference group used in the EUS.

An Example

The complete assignment problem is too complex to present here, involving well over 100 equations representing the various constraints. Rather than describe the problem in generalities, this section presents a simplified example with only two labor types and three tasks. The three tasks are denoted SI (simple), CO (complex), and SU (supervisory); the two labor types are 3 and 6. Hypothetical data for the three tasks appear below.

Task	<u>Labor Type</u>		Workload
	3	6	
<hr/>			
Simple (SI)			
Relative productivity	1.00	1.25	400.00
Check time	0.08	0.00	
Complex (CO)			
Relative productivity	1.00	1.60	300.00
Check time	0.11	0.04	
Supervisory (SU)			
Relative productivity	1.00	1.30	
Check time	0.06	0.04	

The task assignments are indicated by variables such as SI3, which measures the hours of type-3 labor assigned to tasks SI. Similarly, SU6 denotes the number of hours that type-6 personnel devote to the supervisory task. The following equations state the problem:

Minimize: SI3 + CO3 + SU3

Subject to:

$$\begin{aligned} 1.00 \times \text{SI3} + 1.25 \times \text{SI6} &\geq 400.00 \\ 1.00 \times \text{CO3} + 1.60 \times \text{CO6} &\geq 300.00 \end{aligned} \quad \text{(Workload constraints)}$$

$$\begin{aligned} 0.08 \times \text{SI3} + 0.11 \times \text{CO3} + \\ 0.04 \times \text{CO6} + 0.04 \times \text{SU6} &\leq 1.30 \times \text{SU} \end{aligned} \quad \text{(Check-time constraint)}$$

$$\begin{aligned} \text{SI3} &\geq 0.3 \times (\text{SI3} + \text{CO3} + \text{SU3}) \\ \text{SI3} &\leq 0.8 \times (\text{SI3} + \text{CO3} + \text{SU3}) \\ \text{CO3} &\geq 0.2 \times (\text{SI3} + \text{CO3} + \text{SU3}) \\ \text{CO3} &\leq 0.4 \times (\text{SI3} + \text{CO3} + \text{SU3}) \\ \text{SI6} &\leq 0.2 \times (\text{SI6} + \text{CO6} + \text{SU6}) \\ \text{CO6} &\geq 0.2 \times (\text{SI6} + \text{CO6} + \text{SU6}) \\ \text{CO6} &\leq 0.9 \times (\text{SI6} + \text{CO6} + \text{SU6}) \\ \text{SU6} &\geq 0.3 \times (\text{SI6} + \text{CO6} + \text{SU6}) \\ \text{SU6} &\leq 0.6 \times (\text{SI6} + \text{CO6} + \text{SU6}) \end{aligned} \quad \text{(Work-mix constraints)}$$

$$\text{SI6} + \text{CO6} + \text{SU6} = 0.5 \times (\text{SI3} + \text{CO3} + \text{SU3}) \quad \text{(Labor-type constraint)}$$

The first two equations, which ensure that the required work is accomplished, demonstrate that all requirements for hours of work are expressed in terms of type-3 labor. The time inputs of type-6 labor, SI6 and CO6, are multiplied by the relative productivities for this group in the two tasks (see above). If all the CO work was done by type-6 labor, for example, only 187.5 hours would be required ($300 \div 1.6$).

The third equation (check-time constraint), adds up the check time generated by each of the tasks. Note that type-6 labor in the SI task generates no check time. The equation expresses another limitation imposed in the original study: check time must be performed by a higher labor type than that which generated it, except for type-6. This is why there is no equation for check time performed by type-3 labor, and no entry for SU3 in the single check-time equation.

The large group of work-mix constraints impose reasonable limits on the distribution of time across tasks for each labor type. The first two equations, for example, say that between 30 percent and 80 percent of type-

3 hours must be devoted to the SI task. The second two require that between 20 percent and 40 percent of type-3 hours be spent on the CO task. Because these are the only two tasks open to type-3 labor in this example, the two sets of equations could be combined into one. In the full problem, however, the 13 tasks are divided into four categories, with the constraints applied to each category as a whole rather than to individual tasks. The bounds in the full problem were determined as part of the original study, based on an examination of task workloads among the individuals in each labor type.

The fifth work-mix equation stands alone (no "greater than or equal") because all of the variables in the problem must be positive. Thus, between 0 percent and 20 percent of type-6 hours must be spent on task SI.

Finally, the last equation requires that there be twice as many people in labor-type 3 as in type 6. In the full problem, the mix is fixed across labor types at the distribution within the AGE maintenance specialty that existed when the original study was conducted.

Numerical Results. The following values solve the example problem:

SI3	=	364.13
SI6	=	28.70
CO3	=	91.03
CO6	=	130.60
SU6	=	68.27

Only five constraints are binding: the two workload constraints, the lower limits on CO3 and SU6, and the labor-type constraint. Note that the check-time constraint is not binding; the amount of supervision time is driven by the imposed lower limit, not by the task-generated check time. The same situation arose in the full problem.

To determine the relative productivity of type-6 labor, the problem is solved again with the labor-type constraint replaced by a constraint that the total type-6 hours be less than or equal to the total in the first solution (227.58, equal to SI6 + CO6 + SU6). This does not change any of the values above because meeting the workload constraints still requires 455.16 type-3 hours (twice the type-6). The new constraint is binding, and the shadow price associated with it is the negative of the relative productivity of type-6 labor. Recall that a shadow price measures the effect on the objective function if the constraint is relaxed by one unit. In this case, relaxing the constraint means adding one type-6 hour; the shadow price indicates that type-3 hours could be reduced by 0.92 hours.

This result is certainly counterintuitive, indicating that type-6 labor is less productive than type-3 at the margin. The reason it obtains is that the binding lower limit on type-6 supervision time forces every type-6 worker, including the marginal worker, to devote 30 percent of his or her time to work that, within the problem, is nonproductive. This is not to say that the lower limit makes no sense; it captures the requirement for supervisory work that is not task-related, such as writing performance evaluations and counseling junior personnel. The difficulty is that it is unreasonable to assume that when a senior person replaces some number of junior personnel the total supervision requirement would increase.

A more plausible estimate of the relative productivity of type-6 personnel is obtained when the total for hours of supervisory work (SU6 in this example) is fixed at its value in the first solution. ^{4/} With this done, the relative productivity of type-6 personnel is 1.31.

The Full Problem

Despite the simplicity of the example, it demonstrates all the essential elements of the full problem. Although the initial estimate of type-6 relative productivity in the full problem was not less than one, it was less than the estimate for type-5 personnel. The constraints setting lower limits on supervision time by labor of types 3 through 6 (types 1 and 2 could not supervise) were all binding. Replacing those constraints, which are expressed in percentage terms, with constraints fixing the absolute hours of supervision by each labor type changes an implausible downward-turning experience/productivity profile into a more reasonable one that rises with each step upward through the labor types.

To derive the Case 1 productivity index from the labor-type productivities, this study assumed that the estimate for a given labor type would be the productivity of someone with the average years of service of personnel in that labor type. Type-3 personnel, for example, had an average of about 4 years of service, type-6 an average of about 16.5. Linear interpolation between successive points gave intermediate values.

Sensitivity to the Experience Mix. Between 1979 and 1985, the distribution of enlisted personnel in the Air Force changed considerably. The percentage

4. That is, the lower-bound constraint on SU6 is replaced with a constraint that SU6 = 68.27.

of first-term personnel dropped by about six points, and that of personnel in years-of-service 5 through 10 rose by the same amount. If the AGE maintenance specialty experienced the same change, it would have meant roughly a six percentage-point shift from labor types 1 and 2 to types 4 and 5 (the type-3 percentage would not be strongly affected because type-3 includes both first- and second-term personnel). As noted in Chapter 3, this shift might be expected to affect the relative productivities derived from the AGE maintenance data. In fact, virtually all the effects are insignificant.

Little change occurred in the relative productivities because altering the mix of labor types only caused two changes in the sets of tasks to which the six labor types were assigned. The hours assigned changed, of course, but these changes alone cannot affect marginal productivities; in effect, they move the solution point along a flat portion of the production isoquant. The two alterations in task assignments, which affected labor types 3 and 6, increased the relative productivity of type-6 labor from 1.52 to 1.62. This rise seems anomalous, given that it was caused by increases in the percentages of type-4 and type-5 labor. It appears to result from somewhat unusual patterns of relative productivity within the two affected tasks. Presumably, the patterns are unusual because of the small sample size of the original survey.

Qualifications

In supplying the data, the study's principal investigator noted several cautions. For the most part, these concern the applicability of the study's methods--analysis of individual tasks and linear programming to examine alternative work forces--to the full range of Air Force occupational specialties. Whether they affect the usefulness of the estimated aggregate productivities is unclear.

One caution mentioned by the principal investigator clearly is relevant to the current study. He noted: "The AGE maintenance work center and the general accounting work centers were selected for this study because they showed clearcut promise for the substitutability of one within-specialty labor type for another, for substantial productivity increases with greater worker experience, and, consequently, for a wide range of alternative task allocations and corresponding multiplicity of manpower configurations that could handle the associated workloads." This suggests that substituting experience for numbers may be more feasible in this specialty than is true in other Air Force specialties, and that the relative productivities of senior personnel may be lower in other specialties. These issues are discussed in Chapter III.

The Air Force office that transmitted the data to CBO added further cautions. Of particular relevance to the current study, it noted that "the methodology requires arbitrary assumptions to establish the model's boundaries," and "type of equipment and workload mix vary significantly from base to base." Although the importance of the latter is difficult to assess, one set of constraints that might be classed as "arbitrary assumptions" played a major role in determining the results of CBO's analysis: the work-mix constraints. As noted above, the way in which the lower bounds on supervision time were entered into the problem directly affected the relative productivity estimates. Because of this, and reflecting a desire to be conservative, this study used a procedure that yielded relatively modest estimates of the returns to experience to derive the Case 1 indexes.



